

## **Effect of inclined waves on deeply embedded nuclear facilities**

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Several conceptual designs for advanced reactors show most if not all of the structure is embedded in the soil. The analysis techniques which have been verified and validated for the analysis of surface founded light water reactors may not be directly applicable to deeply embedded reactors. Specifically two effects that may change the in-structure response (ISR) of embedded facilities are: (i) the effect of the kinematic interaction becomes more prominent as the embedment depth increases; (ii) non-vertically propagating waves, which are usually not considered for surface founded facilities, may be more important for deeply embedded facilities and may result in nonlinear effects such soil separation/gapping and rocking behavior of the facility. A more detailed and comprehensive study is needed to understand the impact of these effects on ISR of embedded nuclear facilities.

A parametric study is presented to understand the 3-D nonlinear response of embedded nuclear facilities to non-vertically propagating seismic waves. The inclined wave field is generated from source-to-site simulations using a representative earthquake source and the location of the source is varied with respect to the location of the embedded facility. The embedment depth of the nuclear containment facilities is also varied to obtain a better understanding of the effect of embedment. This 3-D nonlinear analysis of the soil-structure ensemble is conducted using the soil structure interaction (SSI) tool MASTODON developed on Idaho National Lab's open source MOOSE finite element framework. To reduce computational effort, domain reduction method developed by Bielak et al. (2003) is used to separate the problem into two parts (i) source-to-site simulation without the nuclear facility and (ii) response of the structure and the soil around the structure to the inclined wave field generated from the source-to-site simulations. This study will shed light on the applicability of the existing analysis techniques to embedded nuclear facilities and will help develop alternate techniques where required.